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AIR COMMAND AND STAFF COLLEGE

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IMPROVING WARTIME SPARES SUPPORT TO AMC:

**AN ANALYSIS OF KC-135 READINESS SPARES PACKAGES
DURING OPERATION ALLIED FORCE WITH A LOOK TO THE
FUTURE AND SUPPORT OF THE AEROSPACE EXPEDITIONARY
FORCE**

by

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Preface

In looking at readiness spares packages and their ability to support flying operations, I was lucky to have access to the Aircraft Sustainability Model. This model is grounded in some fairly sophisticated mathematical concepts on inventory management and the probability of backorders. However, I focused on the very basics in Part 2 because I truly believe that, in general, the best answers are usually simple and are related directly to an understanding of the basics. This should make this report easier to read for those not involved in inventory management, and these readers' understanding could be important to future logistics.

The result of this project is a better understanding of the cost and customer service trade-off provided by readiness spares packages. It could prove useful as groundwork for more research, or possible even as a training tool. The project couldn't have been completed without assistance.

Major David Smith, my faculty research advisor, was a great help in this effort. In addition, I owe thanks to Maj Marvin Arostegui, Assistant Professor at the Air Force Institute of Technology, and Capt Kevin Gaudette from the Air Force Logistics Management Agency. These two people are supply officers extraordinaire, fine thinkers of inventory theory, and Kevin is the sponsor of this paper. If the future of inventory theory rests with Marvin, Kevin and those like them, we're in good hands. Thanks to Capt Bugado and SMSgt Hamilton, who provided needed information from AMC Headquarters. Maj David (DC) Cohen, KC-135 pilot, provided invaluable insight into tanker operations. Discussions with DC framed the direction of this analysis. Finally, I'd like to thank my fiancé, Cindy, for her support in all that I do.

Abstract

This project investigated policy for readiness spares packages (RSPs) and the level of customer service existing aircraft spares provided to the air refueling fleet during Operation ALLIED FORCE. Then, assuming ALLIED FORCE as representative of future Aerospace Expeditionary Force (AEF) deployments, the project investigated how current wartime spares policies and computations could support future tanker operations. Part 2's discussion builds an understanding of the functions and costs of inventory. Then, this knowledge is applied to the Air Force's reparable item inventory system. Customer service and costs were the project's measures of interest, as they represented the significant trade-off when decisions regarding RSP authorizations are made. For ALLIED FORCE, historical data show that operations were remarkably successfully in spite of low fill rates for wartime spares. Depot response improved to offset the poor initial inventory position. Further analysis, using the Aircraft Sustainability Model, showed the effect an ALLIED FORCE scenario can have on future operations. Specifically, "what-if" analysis demonstrated that operations would not meet the desired aircraft availability metric under current policies. In these cases, the project demonstrated depot response's capability to offset inadequate inventory policies. Recommend further research using more specific ALLIED FORCE data to apply to future AEF deployments.

Part 1

Introduction

The battle is fought and decided by the quartermasters before the shooting begins.

— Field Marshall Erwin Rommel

Operation ALLIED FORCE, sometimes called the Air War over Serbia, presented the Air Force with an operational experience that is perhaps more indicative of future Aerospace Expeditionary Force (AEF) operations than has been experienced in the past. This is important in that it provides a new framework within which to analyze the ways in which we plan for war.

Research Objective

With the use of ALLIED FORCE data and the assumption that ALLIED FORCE will be more indicative of the needs of the AEF, it is possible to study aircraft wartime spares planning and its support of future operations. Specifically, it is possible to look at Readiness Spares Packages (RSPs) to determine if current policies and computational assumptions need to be changed to better support the AEF concept. In this research project, two primary questions will be addressed. The first is “How did authorized RSPs support operations during ALLIED FORCE?” The second question is “How well do current RSP policies and computational assumptions support possible AEF deployments?”

Significance

Of great interest in today's Air Force is the ability to provide logistics support to match more carefully tailored force employment concepts. Rapid movement of supplies in the pipeline between factory and flight line provides a "reach back" sustainment capability and allows for a much-needed smaller logistical footprint in theater. A focused logistics system provides the flexibility and responsiveness required of the Air Force agile combat support competency.¹

Through analysis of aircraft wartime spares planning, it is possible to tailor the logistics effort to support future concepts such as the Aerospace Expeditionary Force. Specifically, this research project, sponsored by the Air Force Logistics Management Agency (AFLMA), does exactly that for the planning of readiness spares packages. This effort, to a degree, parallels efforts currently underway within the AFLMA and also some efforts undertaken by the Logistics Management Institute (LMI), leading analysts of spares support.

Limitations

Unfortunately, the scope of this research project had to be limited due to a number of factors. First, the time and page criteria of the project were a limitation. This requirement resulted in limiting this study to one weapon system. The KC-135 was selected based on a couple of reasons. The main reason, though, is the sponsor requested an Air Mobility Command focus since other efforts are working the fighter aircraft picture. From there, the KC-135 was chosen because it had not been studied in this context. Additionally, security classifications of the WMP planning factors forced the paper to use notional data. This data can still show the resulting relationships; however, a look at the same type of analysis with the actual planning factors is recommended. Finally, the scope of the analysis was limited by the author's knowledge of the Aircraft Sustainability Model. This model is very user friendly and can be an

excellent analysis tool for the novice; however, it deals with some complex concepts and can perform much higher levels of analysis in the hands of an expert.

Notes

¹ Air Force Doctrine Document (AFDD) 1. *Air Force Basic Doctrine*, September 1997, p 38.

Part 2

Inventory within a Logistics System

I don't know what the hell this 'logistics' is that Marshall is always talking about, but I want some of it.

— Fleet Admiral E.J. King, 1942

Today, as in Fleet Admiral King's day, logistics is a concept whose need is evident, yet the concept of logistics is so broad that it is not easily definable. It is often referred to as supply chain management, integrated resource management, or other related concepts. At the same time, logistics is often referred to by its various functions, such as supply, transportation, or maintenance. However, it has been suggested the best way to understand logistics is to get back to basics.¹

In getting back to basics, we do know, from our joint doctrine, that logistics is combat power's foundation.² And, from the Air Force perspective, logistics fall within the core competency of Agile Combat Support, which requires highly responsive support as the combat forces are deployed forward.³

As we continue to break this down to basics, responsiveness is the keystone principle of logistics.⁴ One method to provide responsive force support is through the levels of inventory within a logistics system.

This chapter will attempt to get back to basics by developing an understanding of inventory management (functions and costs of inventory) and how inventory can provide service to the

customer. Customer service metrics will show how inventory can provide the logistics principle of responsiveness. Then, this chapter will build on the basics by describing a portion of the Air Force's inventory system, with a focus on specific wartime policies that were developed to be the foundation of our combat power.

Inventory—Back to Basics

All businesses and institutions require materials and supplies that are carried either for sale or to provide inputs or supplies to the production process. These materials and supplies are called inventory.⁵ Inventory serves a number of functions within a firm, such as balancing supply and demand or protecting against the uncertainty of demand. Because of the functions performed by inventory, a firm holds inventory to provide a certain level of customer service. However, this customer service has an associated cost. Hence, it is easy to see the importance of properly managing inventory. This section will cover these aspects of inventory.

Functions of Inventory

Inventory serves five purposes within a firm. These are:

1. Inventory enables the firm to achieve economies of scale
2. Inventory balances supply and demand
3. Inventory enables specialization in manufacturing
4. Inventory provides protection from uncertainties in demand and order cycle
5. Inventory acts as a buffer between critical interfaces within the channel of distribution⁶

Economies of Scale. Inventory makes it possible to create economies of scale within the functions of purchasing, transportation, or manufacturing. For example, volume purchases will often bring smaller unit costs. Also, large volume shipments will bring transportation economies, especially when that results in full truckload or full railcar shipments. Finally,

inventory creates economies of scale within manufacturing by allowing the manufacturer to schedule longer production runs with few production line changes.⁷

Balancing Supply and Demand. Different conditions exist that make it necessary to manufacture finished products in excess of current demand levels and place them into inventory. For example, manufacturers of seasonal items such as snow shovels may need to produce them in advance of the need and place them into inventory because their production rate cannot respond quickly to the demands of a winter storm. The decision to hold inventory will allow the manufacturer to avoid the costs of developing production capacity to match peak demand periods, will avoid wide fluctuations between idle and production time, and will provide a more stable workload for its workforce.⁸

Specialization. Holding inventory in large mixing or distribution warehouses, as done by chain stores such as Wal-Mart and Target stores, allows the manufacturers who supply them to specialize in products that it manufactures. This specialization results in better manufacturing processes, longer production runs, transportation efficiencies, and other benefits.⁹

Protection from Uncertainties. In many cases, the demand for a product varies greatly over time. This can be caused by seasonal influences such as holidays, or simply by unanticipated demand. Holding inventory provides protection from these uncertainties by reducing the likelihood of a stockout due to unanticipated demands.¹⁰ This inventory is often called safety stock.

Buffer. Buffer inventories are held between critical nodes of a distribution channel. These critical nodes include production, distribution, intermediary suppliers, the final consumer, and others. Since these critical nodes can be geographically separated, this buffer inventory provides time and place utility.¹¹

Customer Service and Costs

Although inventory is held to provide the functions discussed in the previous paragraphs, the main purpose to hold inventory is to maximize customer service. Customer service, in this situation, is defined in terms of having items available when the customer needs them. In the commercial sector, customer service is measured in various ways. Some common examples are percentage of orders shipped on schedule, number of backorders, percentage of line items shipped on schedule, and order-days out of stock.¹²

While customer service is an important criteria to a firm, holding large amounts of inventory to ensure a stockout never occurs is not always possible because of the costs involved in holding inventory. These costs include item costs, carrying costs, ordering costs, stockout costs, and capacity-related costs.¹³

Item Cost. Item cost is simply the purchase price of the item, and this price includes transportation, custom duties, and insurance. For items that are manufactured in-house, item costs include all associated direct costs, such as direct material, direct labor, and factory overhead.¹⁴

Carrying Cost. Categories of carrying costs include capital costs, storage costs, and risk costs. These costs have a direct correlation with the amount of inventory held. For example, capital cost is the cost of money invested in inventory that subsequently cannot be invested elsewhere. Storage costs include the cost of the storage location and the manpower required to store inventory. Finally, risk costs include the costs incurred due to pilferage, obsolescence, product deterioration, or damage caused during handling.¹⁵

Ordering Cost. As opposed to carrying costs, which correlate directly with the quantity of inventory, ordering costs are not affected by quantity. Instead, they depend on the number of orders placed in a year. These costs include basic items such as the cost to prepare the order,

follow-up, receive the order, account for the order and authorize payment. Ordering costs can also include manufacturing costs as a result of setup and teardown to run numerous orders, and may include the cost of lost capacity due to numerous setups and teardowns. Placing fewer orders for larger quantities can reduce ordering costs; however, this will increase inventory carrying costs.¹⁶

Stockout Cost. When demand for an item exceeds its supply, the resulting stockout condition carries a number of costs with it. These include the cost of back orders, lost sales, and possibly lost customers.¹⁷

Capacity-related Cost. When output levels in a manufacturing firm must be changed, it results in capacity associated costs. Examples include costs of overtime, hiring, training, extra shifts, and layoffs. These costs can be minimized through the use of level production runs; however, level production runs will build inventory in slack periods and may result in stockouts during peak periods.

Inventory Management

When you consider these five categories of costs, it is obvious that holding large amounts of inventory to assure 100% customer service can be an expensive proposition. Hence, there is a relationship between customer service and costs. This relationship drives inventory managers to ask a number of questions. For example, are you willing to accept backorders and risk levels of customer service in order to save the costs of holding inventory? Or, do you expend large amounts of capital because a stockout is unacceptable? These questions highlight the trade-off between customer service and inventory costs. However, in light of the fact that firms may carry a large number of items in stock, inventory managers must ask one additional question: How

much effort are you willing to expend to manage your inventory in light of the costs involved to manage and store inventory? These questions form the basic purpose of inventory management.

ABC Inventory Control. When forced to decide the level of effort to expend in managing inventory, inventory managers will often divide inventory into three classes based on costs or importance. Then, the inventory management effort and methods will be matched with the different classes. For example, the most important or costly items (usually the top 5% of the items [class A]) will be managed more precisely than any of the less costly items. The moderate cost items (usually the next 15% [class B]) deserve some type of special management, while the inexpensive items (the other 80% [class C]) do not require any special management effort.¹⁸

The previous paragraphs demonstrate how knowledge of the functions of inventory leads to an understanding of the relationship between customer service and costs. This relationship is the main concern of inventory management. Then, ABC analysis, a method of inventory management, was presented to show how inventory managers concentrate management efforts on those items where their efforts will have the most benefit. From here, attention will focus on how the Air Force handles inventory; specifically, its high cost (class A) inventory items.

The Air Force Repairable Item Pipeline

Within the Air Force, the management of high cost inventory items (those that would be considered class A items under ABC inventory control) is handled within something referred to as a repairable item pipeline. This repairable item pipeline is an inventory system that can be described as follows:

A repairable item inventory system is a system used for controlling items that are generally very expensive and have long acquisition lead times. Hence, it is more economical to design these items so they are repaired after they fail, rather than treating them as consumable items, which are disposed of after use. A standard military repairable-item inventory system consists of a repair facility (depot)

dedicated to support several locations (bases) dispersed over an extensive geographical region where equipment (aircraft) is assigned. Over time, equipment malfunctions occur due to the failure of a specific item internal to the equipment. A corresponding serviceable item is then obtained from an inventory location and installed on the malfunctioning equipment, thereby restoring it to full operational capability. The failed item is tracked as it is shipped to the repair facility, scheduled for repair, and subsequently shipped in a serviceable condition back to an inventory location.¹⁹

A graphical depiction of the Air Force reparable item pipeline can be found at Appendix A.

Functions of Inventory

By looking at the reparable item pipeline depicted at Appendix A in comparison with the functions of inventory discussed previously, it is easy to see how inventory in the pipeline can prove beneficial to the Air Force. For example, there are many critical nodes within the system that are geographically separated. Therefore, buffer inventories can provide time and place utility. Also, since demand for an item is based on the item's failure, holding inventory can protect against the uncertainty inherent in such a system. Inventory can also allow specialization to occur, only this time for the repair facility in place of the manufacturing facility, a unique aspect of the reparable item pipeline due to its repair vice replace criteria.

Customer Service and Costs

Customer service, as mentioned previously, is defined in terms of having items available when the customer needs them. This definition is true for the Air Force also. In the Air Force, it is measured differently than in the commercial world. It is measured in terms such as the NMCS rate (% of aircraft that are Not Mission Capable due to Supply of an item), FMC rate (% of Fully Mission Capable aircraft), fill rate (% of authorized readiness spares package on-hand), issue and stockage effectiveness (% of time supply had what the customer ordered and % of time supply

had what it decided to stock), and aircraft availability (number of aircraft available to fly on a certain day).

With the high cost items within the Air Force reparable item pipeline system, it is cost-prohibitive to stock inventory to avoid all possibilities of a stockout. Again, the trade-off between cost and customer service comes into play. For the reparable item pipeline, the pipeline quantity decisions to optimize costs and customer service are made through the use of an Air Force Materiel Command system called the D041.

D041. The D041 system (the Recoverable Consumption Item Requirements System) is a management information system used by the Air Force to compute the worldwide requirements and inventory levels for reparable items. It does this by breaking the pipeline (see Appendix A) into 11 segments, then computes or assigns quantities for each segment. These segments are: 1) organizational and intermediate maintenance (OIM) operating requirement, 2) total OIM base stock level requirement, 3) OIM depot stock level requirement, 4) Management of Items Subject To Repair (MISTR) non-job-routed (NJR) requirement, 5) Programmed Depot Maintenance (PDM) NJR requirement, 6) engine NJR requirement, 7) total overhaul condemnations requirement, 8) total overhaul stock level requirement, 9) prepositioned requirement, 10) prestocked requirement, and 11) additive requirement. When comparing these segments to the drawing at Appendix A, segments one and two occur within the base level block, and segments three through eight occur within the depot level block. Segments nine through eleven are additional requirements established to support additional needs such as wartime.²⁰ All quantities are either computed or assigned within D041 to allow inventory to provide beneficial functions as described previously, and to provide the trade-off between customer service and costs. These inventory calculations are made based on an algorithm designed to provide "marginal analysis."

In marginal analysis, each item's contribution to the goal of aircraft availability per dollar spent is optimized and results in the best availability/cost solution for each segment of the pipeline.²¹ Although not computed within D041, this same "marginal analysis" is used to compute wartime requirements separately, and these quantities are placed in segments nine and ten of the D041 system. Segment nine, the prepositioned requirement, includes items allocated as Readiness Spares Packages (RSPs). These packages are designed to be available to deploy forward along with the fighting unit to a contingency, conflict, or war. These packages are the focus of this research project.

Readiness Spares Packages

Readiness Spares Packages can be separated into two types, Mobility Readiness Spares Packages (MRSPs) for units that deploy, and In-place Readiness Spares Packages (IRSPs) for units that fight in place. In either case, the management of these spares is governed by Chapter 14 of Air Force Manual 23-110, USAF Supply Manual. This manual states, "The major objective of the RSP Program is to support national strategy in consonance with the guidance issued by the Office of the Secretary of Defense. Specifically, the Air Force objective is to authorize, acquire on time, preposition, prestock, and maintain in a serviceable condition ready for use, all RSP needed to support the wartime activities specified in the War and Mobilization Plan (WMP)."²² RSPs are considered supplies of vital importance whose requirements are determined based on the maintenance capabilities available at the wartime location. Again, as with all inventory decisions discussed so far, items and quantities within RSPs will be the minimum necessary to support the WMP tasked mission—the customer service/cost trade-off.²³ These items and quantities will be provisioned according to the quantities computed by the Aircraft Sustainability Model.²⁴

The Aircraft Sustainability Model

Air Force inventory managers, in their wartime planning role, must calculate RSP items and quantities to support weapon-system readiness. To do so, they must take into account a wide range of operational situations along with the characteristics of each weapon system component. Operational situations are characterized by the weapon system's flying-hour program. Weapon system component characteristics include projected failure rates, repair times, and procurement costs. The Aircraft Sustainability Model (ASM), developed by the Logistics Management Institute (LMI) for the United States Air Force, combines these operational situations and component characteristics into a mathematical statistical model for use by inventory managers. The ASM computes optimal spares mixes to meet the ultimate goal of the logistics system: available aircraft.²⁵

Available aircraft is considered the ultimate goal of the logistics system because internal supply system performance measures such as fill rate have weaknesses.²⁶ One common example in the supply community is in reference to an A-10 RSP fill rate. If this RSP contains 99% of its authorized quantity of items (fill rate), it appears to be a healthy situation. However, if the one percent of the items not available happens to be a spare needed to repair the A-10's gun (its primary weapon), a 99% fill rate does not provide a mission-available aircraft. Also, fill rate does not capture information about the complexity of the aircraft being supported. The LMI report describes this best:

All else being equal, more complex aircraft require a higher component fill rate to reach a given availability than do simpler aircraft. ...availability is defined as a product of probabilities—the probability that the aircraft is not missing its first component, times the probability that the aircraft is not missing its second component, and so on. An aircraft with more components has more factors in the product, and since each probability is less than 1.0, the product will tend to be smaller. Thus using a fill rate criterion...leads to a bias in favor of the less complex aircraft types.²⁷

The LMI report concludes "in the difficult cost-effectiveness choices that military logistics planners must make, the difference between fill rate and aircraft availability is critical."²⁸

To find the aircraft availability solution, the ASM computes an optimal spares mix by combining two systems, the Marginal Analysis System (MAS) and the Cross-Linker. The MAS, driven by the operational situation (sortie rates and durations), is a multi-echelon, multi-indenture model that optimized spares support for a single day of the scenario. Multiple runs of the MAS are used to analyze multiple days of the scenario. These multiple runs are combined by the Cross-Linker to optimize spares support for the entire duration of the scenario.²⁹

The output of the model provides an optimal 'shopping list.' This list can show, given a specific funding level, the mix of spares that will provide the highest aircraft availability rate. Or, ASM can take a given availability rate, called the direct support objective (DSO), and develop the least cost spares mix to reach that target.³⁰

Summary

This purpose of this chapter was to build an understanding of the role inventory and the management of inventory plays within a logistics system. Inventory provides function to a firm by enabling the firm to achieve economies of scale, to balance supply and demand, to specialize in manufacturing, to protect against uncertainties in demand, and to act as a buffer between critical interfaces within the channel of distribution. Because of these functions, inventory contributes to the level of customer service a firm can provide. Customer service is defined as having items available when the customer needs them. When the firm holds inventory, it often provides customer service, but also incurs costs. These costs are categorized as item costs, carrying costs, ordering costs, stockout costs, and capacity-related costs. Due to the customer service and cost trade-off, inventory managers often use ABC Inventory Control to divide

inventory into management classes. Under this system, the most expensive (Class A) items are managed more precisely than the less costly items.

In the Air Force, Class A-type inventory items are managed within the reparable item pipeline. Within this pipeline, inventory performs the same functions as described previously. These functions, again, lead the Air Force to hold inventory in order to provide customer service. Holding inventory in the Air Force also incurs the same costs. The customer service/cost trade-off for the 11 segments of the reparable item pipeline is computed by the Recoverable Consumption Item Requirements System (D041). As part of the pipeline, Readiness Spares Packages (RSPs) are included to support wartime activities specified in the War and Mobilization Plan (WMP). Deciding the composition of an RSP again is based on the same customer service/cost logic as with the D041. In the case of RSPs, the optimal mix of spares is calculated through a program called the Aircraft Sustainability Model.

The remainder of this paper will deal specifically with RSPs. First, analysis of Operation ALLIED FORCE data will answer the question, "How did authorized RSPs support operations during ALLIED FORCE?" After that, the next chapter will answer the question, "How well do current RSP policies and computational assumptions support possible AEF deployments?"

Notes

¹ Blazer, Douglas J., PhD, "Improving the Air Force Logistics System—Getting Back to Basics", *Logistics on the Move*, Air Force Logistics Management Agency, April 1999, p 20.

² Joint Pub 4-0. *Doctrine for Logistic Support of Joint Operations*, 27 January 1995, p I-1.

³ Air Force Doctrine Document (AFDD) 1. *Air Force Basic Doctrine*, September 1997, p 34.

⁴ Joint Pub 4-0. *Doctrine for Logistic Support of Joint Operations*, 27 January 1995, p II-1.

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⁶ Stock, James R. and Douglas M. Lambert, *Strategic Logistics Management*, 2nd ed. Homewood, IL: Richard D. Irwin Inc., 1987, p395.

⁷ Ibid, p 396.

⁸ Ibid, p 396-397.

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- ⁹ Ibid, p 397.
- ¹⁰ Ibid.
- ¹¹ Ibid, p 398.
- ¹² Arnold, J.R. Tony, *Introduction to Materials Management*, 3rd ed. Columbus, OH: Prentice Hall, 1998, p 228.
- ¹³ Ibid, p 230.
- ¹⁴ Ibid.
- ¹⁵ Ibid, p 230-231.
- ¹⁶ Ibid, p 231-232.
- ¹⁷ Ibid, p 233.
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- ²¹ Briefing. King, Randall, PhD, and Col John Gunselman. Subject: RSP Computation: Policy and Practice (presentation to Gen John Jumper, USAFE Commander), December 1, 1999.
- ²² Air Force Manual (AFM) 23-110. *USAF Supply Manual*, April 99, Chapter 14, p 8.
- ²³ Ibid, p 9.
- ²⁴ Ibid, p 17.
- ²⁵ Slay, F. Michael, et al. *Optimizing Spares Support: The Aircraft Sustainability Model*. LMI Report AF501MR1. McLean, VA: Logistics Management Institute, October 1996, p 1-1—1-2.
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- ²⁷ Ibid.
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- ²⁹ Slay, F. Michael, and Randall M. King. *Prototype Aircraft Sustainability Model*. LMI Report AF601R2. Bethesda, MD: Logistics Management Institute, March 1987, p iii-iv.
- ³⁰ Slay, F. Michael, et al. *Optimizing Spares Support: The Aircraft Sustainability Model*. LMI Report AF501MR1. McLean, VA: Logistics Management Institute, October 1996, p iv.

Part 3

KC-135s in Operation ALLIED FORCE

Given the nature of the air campaign and the many obstacles tankers had to overcome, their accomplishments were remarkable.

— Lt Gen William J. Begert, USAF

Operation ALLIED FORCE began on 24 March 1999, and ended 78 days later as the largest combat operation in NATO's history. Thirty eight thousand combat sorties succeeded in delivering a punishing air offensive with virtually no loss to NATO forces. Because of the pressures brought to bear, Slobodan Milosevic withdrew his Serbian forces from Kosovo and acquiesced to NATO conditions.¹

Active and reserve component air refueling aircraft (tankers) played a key role in Operation ALLIED FORCE. They provided multiple air bridges for aircraft transiting to the theater, and provided refueling support for over 24,000 combat sorties.² Tankers, 112 active and 63 reserve aircraft, flew over 5000 sorties and delivered 250 million pounds of fuel. This operation differed from DESERT STORM, as tankers were required to continuously support reinforcement and sustainment efforts until the end of hostilities. Major General Begert, the coordinator of the operation's offensive and defensive air operations said, "Given the nature of the air campaign and the many obstacles tankers had to overcome, their accomplishments were remarkable."³

Based on the final results of tanker operations during ALLIED FORCE, is it safe to assume that the aircraft spares in the inventory, and specifically the spares mix in readiness spares packages were at optimal levels to support this operation?

Research Question #1

How did authorized RSPs support operations during ALLIED FORCE? Or, based on the limitation of this project to one weapon system, the KC-135, the question should be "how did authorized RSPs support KC-135 operations during ALLIED FORCE?"

The inventory discussion in the previous chapter focused on the customer service/cost trade-off. In Operation ALLIED FORCE, the operation began with a certain quantity of inventory available on the first day of the effort. Hence, the initial inventory costs were already incurred. Because of this fact, this analysis will focus on customer service measures as an answer to the research question.

Fill Rate

As a reminder, fill rate is the percentage of authorized reparables actually on-hand for an RSP. Authorized RSP quantities are computed using the Aircraft Supportability Model (ASM) to provide an optimal mix of spares to support the War and Mobilization Plan (WMP) for 30 days and to provide a sustained direct support objective (DSO) of 83%. The DSO is the number of aircraft desired available for the operation.

During Operation ALLIED FORCE, 17 of the total 40 RSPs for KC-135s were deployed. At the beginning of the operation, those RSPs deployed had a fill rate of 68%. At the end of the operation, those fill rates had improved to 77% (Fig. 1).⁴

KC-135 MRSP FILL RATES

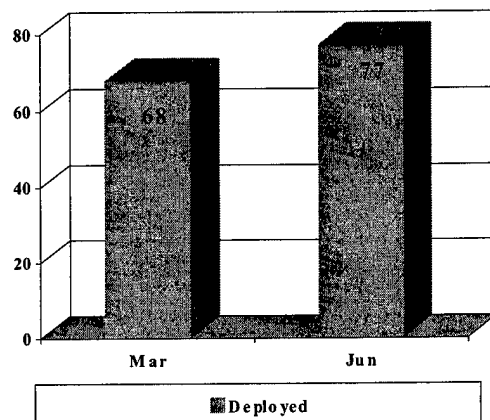


Figure 1 Deployed KC-135 Fill Rates

Stockage/Issue Effectiveness

Stockage effectiveness, as defined previously, is the percentage of total spares authorized to be held in inventory that are available upon customer request. While deployed, the RSP stockage effectiveness for reparable items was 98.4%.

Issue effectiveness, again, is the percentage of customer requests that were filled by items in the inventory. The significant difference between stockage and issue effectiveness is that stockage effectiveness uses authorized inventory levels in its ratio. Issue effectiveness is based on filling any request, not just requests for items authorized in the inventory. Therefore, issue effectiveness will usually be lower, but is more representative of the customer's view of support. For deployed operations, the issue effectiveness of reparable items was 90.6%.^{5, 6}

Aircraft Availability

Available aircraft is considered the ultimate goal of the logistics system. During ALLIED FORCE, the aerial refueling fleet was forced to endure extended sortie durations due to tanker

basing locations that extended from Budapest, Hungary to Mont-de-Marsan in France. Also, operations required high tanker usage rates to support the combat and airlift forces. Even so, the KC-135 maintained an actual mission-capable rate of 78%.⁷

Analysis

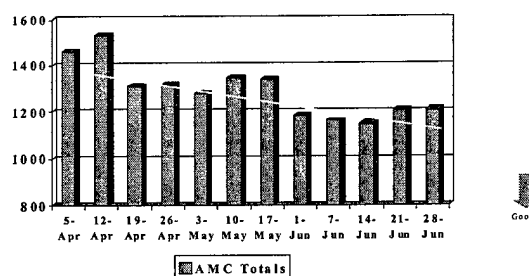
In the big picture, readiness support packages, along with the entire logistics system, supported operations in an outstanding manner. They contributed to victory. They allowed airpower to play the deciding role in a major theater war.⁸ However, there are insights to be gained by breaking the system down into its measured criteria.

Fill Rate. RSPs are often measured by their fill rate. In ALLIED FORCE, having to begin operations with RSP fill rates at 68% should attract immediate attention. One could quickly jump to the conclusion that inventory reductions are mandated since 68% of what was thought to be required produced these types of sortie numbers and positive results. The excellent stockage and issue effectiveness numbers that were achieved in theater could support this conclusion. However, this 68% fill rate only produced 78% available aircraft—the goal of a KC-135 RSP is 83%. In addition, it is wise to remember that RSPs were developed to support a 2 Major Theater War (MTW) scenario, not another ALLIED FORCE. If we were to go to war according to the WMP, 100% fill rate is required to produce the desired DSO. Anything less has to be offset in maintenance actions (more base-level repairs, higher cannibalization rates, etc.), a faster logistics pipeline, or in fewer numbers of available aircraft. While fill rates are not the best measure of customer support, starting behind the power curve adds pressure to the rest of the pipeline.

Depot Response. One area that may be able to absorb the pressure of a low fill rate are the depots. By surging output and expediting repairs, the depots can offset a less-than-desired fill rate. In ALLIED FORCE, depot response did exactly that. The depots expedited efforts to fill

backorders from units involved in ALLIED FORCE. These backorders were identified with a special project code that identified them with ALLIED FORCE and prioritized them above normal peacetime backorders. Fig 2⁹ shows the reduction in backorders during this period. Depot response not only reduced backorders, but also improved deployed RSP fill rates from 68% to 77% by the end of the operation. The risk in prioritizing ALLIED FORCE backorders above others is to jeopardize the readiness of other units. However, in this case, the depots not only repaired ALLIED FORCE priorities, they also surged output across the board (Fig 3).¹⁰

9FS REQUISITIONS FOR STRATEGIC AIRLIFT



Backorders for AMC strategic aircraft reduced
-- Improved 28 percent from Apr to Jun 99

Figure 2 ALLIED FORCE Backorder Reduction

OVERALL DEPOT SUPPORT TO AMC

Jul 98 - Jun 99

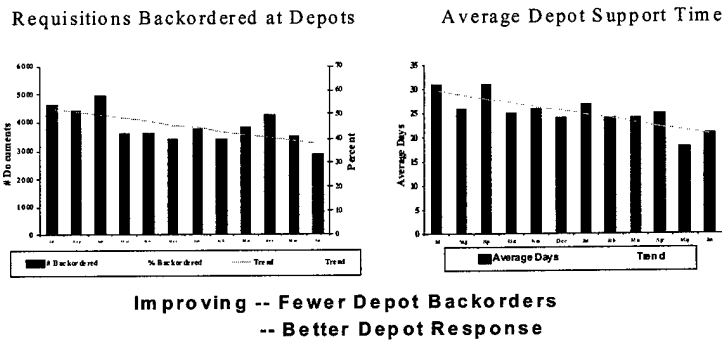


Figure 3 Depot Surge Efforts

Aircraft Availability. As has been said earlier, available aircraft is considered the ultimate goal of the logistics system. RSPs for the KC-135 are designed to provide 83% aircraft availability based on the inputs to the Aircraft Sustainability Model. For ALLIED FORCE, RSPs, along with the rest of the logistics pipeline, fell short of the goal and provided 78% mission capable aircraft. It would be of interest to compare the data within the model (pipeline times, failure rates, cannibalization actions, etc.) with the actual data for the individual packages that deployed to ALLIED FORCE. This individual data would be more comprehensive and indicative of real operations; unfortunately, analyzing each individual package is beyond the scope of this project.

Summary

Operation ALLIED FORCE, from the tanker perspective, can be considered a remarkable success. However, analysis of inventory customer service criteria show that operations did not occur exactly as planned. Fill rates were lower than desired at the beginning of the operation. In spite of that, stockage and issue effectiveness numbers remained incredibly high. Low fill rates,

combined with a flying schedule that was more demanding than planned for a major theater war would not be expected to have stockage and issue effectiveness numbers as high as those achieved. One possible explanation was that the reparable item pipeline supplied parts at an increased rate. Depot response played a significant role in offsetting initial deficiencies in the fill rate. In addition, the depot continued to supply spares and reduce backorders to all customers. In the end, spares flowing through the reparable item pipeline failed to meet the expected 83% aircraft availability rate, but the final 77% rate did provide enough aircraft to bring overall success.

This information is descriptive of an operation that may be more indicative of future operations. Based on this assumption, analysis of Operation ALLIED FORCE can help prepare Aerospace Expeditionary Forces, and their inventory managers, for the future.

Notes

¹ Senate Armed Services Committee, *Hearing On Kosovo After-Action Review*, Joint Statement of William S. Cohen, Secretary of Defense, and General Henry H. Shelton, Chairman of the Joint Chiefs of Staff, 14 October 1999.

² Ibid.

³ Lt Gen William Begert, "Kosovo & Theater Air Mobility," *Aerospace Power Journal* XIII, no. 4 (Winter 1999): p 14.

⁴ Headquarters Air Mobility Command, LGSWA, Point Paper: "KC-135 Readiness Spares Packages (RSP) Fill Rates for Kosovo" 2 July 1999.

⁵ Briefing. Headquarters Air Mobility Command, LGSWA. Subject: Total Deployed Supply Support, 28 May 1999.

⁶ ALLIED FORCE did not officially end until 9 June 1999. This data is from 28 May 1999/1900z.

⁷ Lt Gen William Begert, "Kosovo & Theater Air Mobility," *Aerospace Power Journal* XIII, no. 4 (Winter 1999): p 14.

⁸ Ibid.

⁹ Briefing. Headquarters Air Mobility Command, LGSW. Subject: Noble Anvil—The AMC Support Perspective, nd.

¹⁰ Ibid.

Part 4

Aerospace Expeditionary Force

The world is less stable, predictable, and harmonious than it was during the Cold War, with a whole range of new conflicts, rivalries, and challenges.

— Richard P. Hallion, AF Historian

Threats to American vital interests are much more diffuse today than ever. The end of the Cold War did not mark the beginning of a new era of peace. Instead, American military units deployed around the world to places like the Persian Gulf, Somalia, Bosnia, Rwanda, Haiti, and Kosovo to confront today's largely unpredictable world.

In response to this unpredictable world, the United States Air Force introduced the Expeditionary Air Force (EAF) concept. Under this concept, rapidly deployable airpower packages can be tailored to the situation and launched—ready to operate anywhere in the world in three days.¹ An airpower package under the EAF concept will be called an Aerospace Expeditionary Force (AEF).

Today, ten AEFs have been designated from geographically separate units of the active and reserve force. These forces are made up of a mixture of assets to include fighters, bombers, and support aircraft. At any one time, 2 AEFs are on-call to respond within 72 hours. This “on-call” period will last for 90 days every 15 months.² A draft version of an AEF schedule for AMC units is provided for additional clarification of the concept (Appendix 2).

Research Question #2

An unpredictable world drove the need to establish AEFs. AEFs, then, provide a somewhat unpredictable effect on the reparable item pipeline that is responsible to support them. It is important to use recent history such as Operation ALLIED FORCE to study the current system's ability to support these types of deployments. This leads to the next research question: How well do current RSP policies and computational assumptions support possible AEF deployments? Again, this project will focus on one weapon system, the KC-135, and will use the customer service/cost trade-off as its main criteria for analysis. The methodology will primarily rely on "what-if" analysis of an Operation ALLIED FORCE type scenario through the use of the Aircraft Sustainability Model.

Scenario

To facilitate the "what-if" analysis methodology, ASM inputs were based on a scenario similar to what actually occurred during Operation ALLIED FORCE. This scenario is split into three segments. The subsequent analysis will follow the same three segments, and will focus on the cost and customer service trade-off.

In Operation ALLIED FORCE, tanker aircraft often operated from airfields on the periphery of the theater. Because of this, they were forced to fly missions of longer duration than that planned for a major theater war.³

The fuel a tanker carries for air-refueling purposes is also the same fuel that the tanker burns in its own engines. Therefore, tankers in Operation ALLIED FORCE were not able to loiter the same length of time or provide the same amount of support as normally planned for a major theater war.⁴ They were forced to fly more sorties as a result.

Finally, depot operations, along with the rest of the logistics system, provided "reach back" capability to overcome low initial fill rates of readiness spares packages. This "reach back" ability provided outstanding results in that fill rates at the end of the operation were better than those at the beginning.⁵

What-if Analysis

To start, an initial baseline run was made with the ASM model. This baseline used actual KC-135 package data for a unit with 10 aircraft. Some data input into the model was notional data, as using actual WMP sortie rates and durations would make this project classified. Even with notional data, the relationships will still be visible. The results of the initial run are shown in Table 1.

Table 1 Baseline

	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	219	691	\$7,091,681	83.21%

In the baseline package, ASM computed an RSP to consist of 219 different repairable types. Total number of units was 691. The cost of these 691 spares was over \$7 million, and, as the model is supposed to do, this mix of spares will achieve an 83% aircraft availability rate. The remaining analysis will be compared against these baseline figures.

Increased Sortie Duration. In our scenario, operating from bases on the periphery of the theater increases the sortie duration. This was modeled in ASM by using the baseline package and increasing the sortie duration by 10% and 20%. The results are shown in Table 2.

Table 2 Sortie Duration Test

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	X	Y	219	691	\$7,091,681	83.21%
Test #1	1.1(X)	Y	219	731	7,653,498	83.1%
Test #2	1.2(X)	Y	219	751	8,126,672	83.12%

As you can see, all packages still achieve the 83% goal; however, the number of units and overall costs to reach this goal climbs rapidly with the increase in sortie duration.

Increased Sortie Rate. Now, the inputs to the model will incorporate the next portion of the scenario. By staging tankers on the periphery, they must travel further to meet the aircraft needing fuel. Due to this travel time, they have less loiter time and less fuel to dispense on each mission. This requires more sorties. This was modeled by using the previous model runs with an addition to the sortie rate by 10% and 20%, as shown in Table 3.

Table 3 Sortie Rate Test

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Test #1	1.1(X)	Y	219	731	\$7,653,498	83.1%
Test #1A	1.1(X)	1.1(Y)	219	757	8,282,561	83.68%
Test #1B	1.1(X)	1.2(Y)	219	788	8,730,236	83.07%
Test #2	1.2(X)	Y	219	751	8,126,672	83.12%
Test #2A	1.2(X)	1.1(Y)	219	790	8,753,289	83.05%
Test #2B	1.2(X)	1.2(Y)	219	835	9,346,651	83.05%

Again, the results are along the same lines as before. ASM continues to build packages that will provide the correct percentage of available aircraft. However, it does this by increasing the number of units authorized in a package. This increase in quantity also brings an increase in cost.

Assuming that an increase in costs is not acceptable, the model is run with the original baseline package quantities against the various flying data. When the model is run this way, it

will provide the best available aircraft percentage possible from that mix and quantity of spares.

The results are shown in Table 4.

Table 4 Customer Service Measures

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	X	Y	219	691	\$7,091,681	83.21%
Baseline Package	1.1(X)	Y	219	691	7,091,681	82.92%
Baseline Package	1.1(X)	1.1(Y)	219	691	7,091,681	81.12%
Baseline Package	1.1(X)	1.2(Y)	219	691	7,091,681	80.86%
Baseline Package	1.2(X)	Y	219	691	7,091,681	78.86%
Baseline Package	1.2(X)	1.1(Y)	219	691	7,091,681	78.78%
Baseline Package	1.2(X)	1.2(Y)	219	691	7,091,681	76.57%

These results, instead of showing a change in costs, show the change in customer service. From the baseline of 83%, the worst-case scenario loses almost 7% on our ultimate goal, available aircraft. By comparing the changes in customer service under the tests in Table 4 to the changes in price as shown in Table 3, an interesting phenomenon is noticeable. It appears that aircraft availability is less affected by changes in spares quantities than the costs. If aircraft availability exhibits more robustness than costs, it may be possible, in situations, to give up a smaller percentage of aircraft availability in return for a larger cost savings. The reason behind this robustness is due to the location the desired availability falls on the curve shown in Fig 4. This curve demonstrates the "law of diminishing returns." This phenomenon shows that a desired increase in aircraft availability requires an increasingly larger cost as you get closer to 100%. Also, in reverse, each dollar reduction in cost has an increasingly larger negative affect

on aircraft availability as you get closer to \$0. These results are significant in that they demonstrate that it is virtually impossible to achieve 100% aircraft availability. Also, aircraft availability declines in larger proportion to the number of spares available as you move left on the curve.

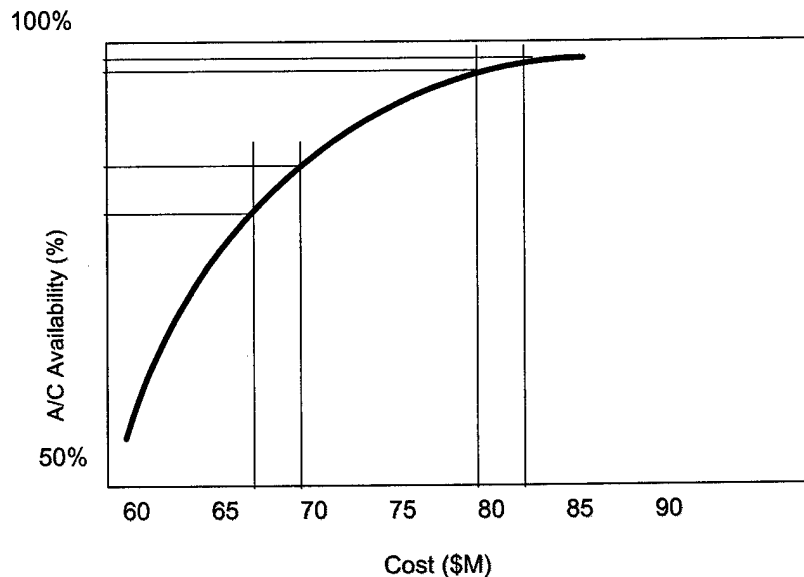


Figure 4 Law of Diminishing Returns

Reach-back Capability. The third portion of the scenario calls for increased response from the depot or other portions of the reparable item pipeline. In the previous models, depot repair does not start until after the model run ends. To depict an increased reach-back capability, the worst-case model has been changed to allow depot repairs to begin on day one. The results are shown in Table 5.

Table 5 Reach-back Test

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Worst-case Package	1.2(X)	1.2(Y)	219	691	\$7,091,681	76.57%
Reach-back Package	1.2(X)	1.2(Y)	219	691	7,091,681	79.30%
Reach-back repair + adds	1.2(X)	1.2(Y)	219	759	8,172,490	83.11%

This model run shows the capability of depot repair to offset an undesirable situation. Depot repair adds nearly 3% of aircraft availability in the first 30 days. This result is quite intuitive—response capability anywhere in the pipeline can provide increased aircraft availability. However, for depots to generate the desired DSO, they will have to improve pipeline response (i.e. shorter repair times, improved transportation, etc.) in addition to starting early. Unfortunately, the costs to provide pipeline response are beyond the scope of ASM. In the end, without pipeline response improvements, the depot will have to add an additional quantity of spares to reach the desired DSO (as shown on the bottom row, Table 5).

Summary

Aerospace Expeditionary Forces were established to deal with the uncertain future. However, if that future requires AEFs to participate in operations similar to Operation ALLIED FORCE, analysis of ALLIED FORCE scenarios can add insight into future needs. This insight can aid the development of new wartime spares and computational policies.

In the analysis presented above, an ALLIED FORCE style scenario was developed and matching inputs were made to the Aircraft Supportability Model. The results of this analysis demonstrated the effects on aircraft availability and costs that a situation like ALLIED FORCE can have. The analysis also found an interesting robustness around aircraft availability. This

robustness provides a cost saving while giving up a much smaller percentage of availability. However, it also shows that fewer spares have an increasingly drastic affect on availability due to the law of diminishing returns. Finally, depot response was improved in the model with the results being predictable—improved aircraft availability. This analysis supports any improvement possible in depot response as extremely beneficial. Subsequently, any actual depot response improvements should be included in the ASM logic. This could provide an incredible amount of cost savings in RSPs.

In the end, current RSP policies and computational assumptions will only support future AEF deployments when the operations tempo of those deployments is equal or less than the WMP scenario. In cases like Operation ALLIED FORCE, that was not true. Therefore, additional pipeline response capability was shown to help offset the shortfall that could occur with high tempo AEF operations.

Notes

¹ Lee, Major Joni R., "Prepositioning: A Logistics Concept for the AEF," Research Report, Air Command and Staff College, 1999, p 3.

² Ibid.

³ Senate Armed Services Committee, *Hearing On Kosovo After-Action Review*, Joint Statement of William S. Cohen, Secretary of Defense, and General Henry H. Shelton, Chairman of the Joint Chiefs of Staff, 14 October 1999.

⁴ Cohen, Major David M., "The Vital Link: The Tanker's Role in Winning America's Wars," Research Report (Draft), Air Command and Staff College, 2000, p 16.

⁵ Briefing. Headquarters Air Mobility Command, LGSW. Subject: Noble Anvil—The AMC Support Perspective, nd.

Part 5

Conclusions and Recommendations

When it comes down to the wire and the enemy is upon you and you reach into your holster, draw your pistol and level it at your adversary, the difference between a click and a bang is logistics.

— Editors of *Loglines*

Aerospace Expeditionary Forces were established to deal with the uncertain future. This uncertainty has implications for inventory in the logistics system. In a world looking to save costs within the Department of Defense, inventory is an easy target. However, it's inventory that provides available aircraft. The trade-off between costs and customer service has been the focus of this research project.

Readiness spares packages provide inventory for a 30-day period of wartime operations. This inventory provides the ultimate customer service measure: aircraft availability. However, they are also quite expensive (a 10-aircraft unit of KC-135s can have an RSP valued in excess of \$7 million).

During Operation ALLIED FORCE, tanker units deployed with readiness spares kits that were at 68% of their authorized inventory level. For AEF operations, that may not attract a great deal of concern, as it is easy to think that an AEF will respond to small-scale contingencies (SSCs). SSCs could easily be viewed as a subset of a major theater war; hence, they won't require the same amount of spares. However, ALLIED FORCE showed that basing options and mission requirements could result in sortie rates and durations higher than those planned in the

WMP. In these cases, responding with an appropriate number of spares will be important for future operations.

Because of this, determining the appropriate number of spares becomes important. The Aircraft Sustainability Model (ASM) is the Air Force's official tool for this purpose. As this project demonstrates, ASM easily shows the cost and customer service trade-off of this inventory decision. And, this project did demonstrate a higher degree of robustness around aircraft availability than it did on costs. This effect can lead to policy changes to reduce inventory in situations where the smaller percentage of available aircraft can successfully perform the mission. In contrast, the project did also demonstrate that diminishing spares availability can have an increasingly negative affect on aircraft availability. Based on this, RSP fill rates should not be allowed to fall out of the area where they demonstrate the robustness around aircraft availability. For further proof, modeling actual data from a number of individual units that participated in ALLIED FORCE is recommended to determine if this relationship exists across the board. It is possible that this relationship varies somewhat to the scenario or weapon system. It is beneficial to continue to analyze this relationship for future improvements.

In this analysis, depot response improvements showed the capability for improving the number of available aircraft. Even though this is quite intuitive, this analysis should provide yet one more reason to continue depot response and pipeline time improvements. These improvements, once quantified, must then be added into the logic of the ASM to allow the Air Force to reduce RSP quantities. With pipeline response improvements, smaller RSPs will maintain or improve aircraft availability while allowing the Air Force to reap inventory cost savings.

Another benefit to improved depot response is the ability to provide support to units in all theaters vice concentrating on units involved in AEF operations. Operation ALLIED FORCE proved the depot's capability to do this.

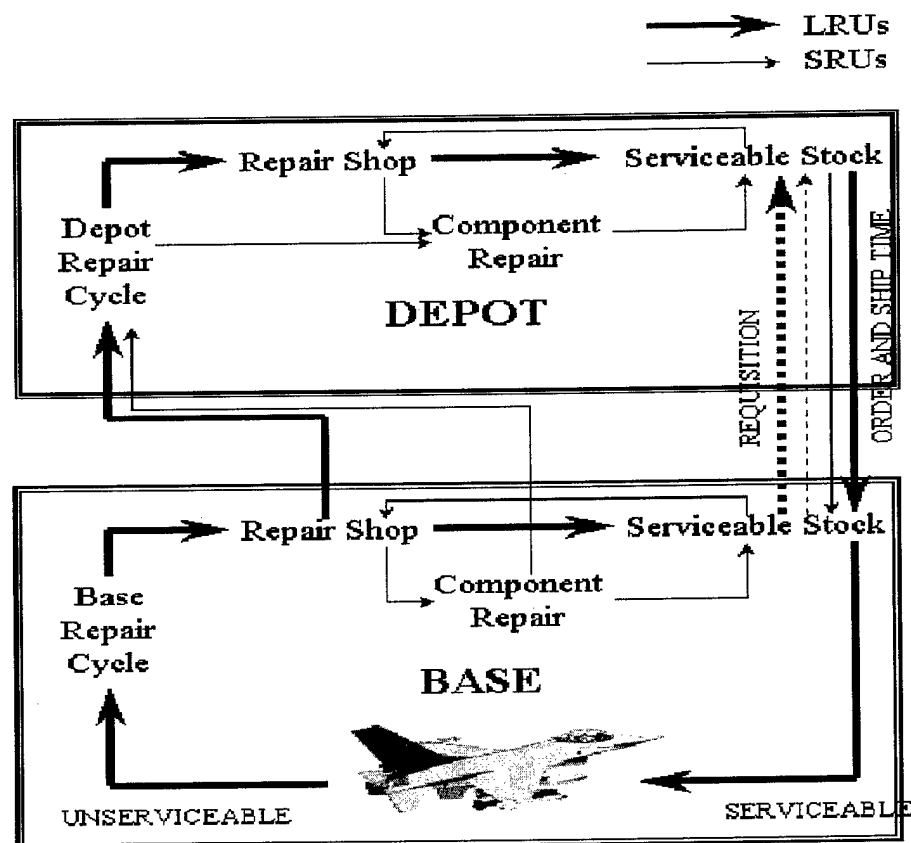
Finally, ASM proved to be a valuable tool. The relationships between customer service and costs are easily demonstrated through the use of ASM. Its use should be encouraged throughout the community responsible for Air Force inventory management. It brings a greater level of understanding to the trade-offs involved in inventory decisions.

In the end, tanker operations in Operation ALLIED FORCE were extremely successful. The inventory policies concerning readiness spares packages supported this operation, even though the beginning inventory balances were less than planned. Some robustness around the available aircraft measure, when compared with cost values, was found via "what-if" analysis. This characteristic has the potential to allow for additional cost savings and should be studied further with actual Operation ALLIED FORCE data. However, there is danger evident if inventory levels fall too far, as was shown in Figure 5. Finally, the Air Force's "reach-back" capability showed potential for improving customer service and reducing costs—these improvements should be institutionalized and then find their way into the ASM logic to reduce the inventory stored in an RSP.

Current RSP policies and computational assumptions will only support future AEF deployments when the operations tempo of those deployments is equal or less than the WMP scenario. In those cases where that is not the case, such as Operation ALLIED FORCE, improved reach-back capability can offset the resulting inventory shortfall.

Appendix A

Air Force Reparable Item Pipeline¹



Notes

¹ Arostegui, Major Marvin A., AFIT/EN. Course Material, LOGM 628, Reparable Inventory Management, Air Force Institute of Technology, nd.

Appendix B

Example: AMC AEF Rotation¹

<p>AEROSPACE EXPEDITIONARY FORCE 5</p> <p>(Vulnerability Window 1 Mar 00 thru 1 Jun 00) LEAD MOBILITY WING 22 ARW McConnell AFB</p> <p>Assigned Squadrons: C-130 2 AS Pope AFB / ANG / AFRC KC-135 344 / 349 ARS McConnell AFB / ANG / AFRC KC-10 60 AMW Travis / 305 AMW McGuire AFB C-21 84 ALF Colorado Springs / 457 AS Andrews AFB</p> <p>On-Call Squadrons: C-130 41 AS Pope AFB KC-135 99 ARS Robins AFB</p>	<p>AEROSPACE EXPEDITIONARY FORCE 6</p> <p>(Vulnerability Window 1 Mar 00 thru 1 Jun 00) LEAD MOBILITY WING 22 ARW McConnell AFB</p> <p>Assigned Squadrons: C-130 2 AS Pope AFB / ANG / AFRC KC-135 97 / 93 ARS Fairchild AFB / ANG / AFRC</p> <p>On-Call Squadrons: C-130 41 AS Pope AFB KC-135 99 ARS Robins AFB</p>
<p>AEROSPACE EXPEDITIONARY FORCE 7</p> <p>(Vulnerability Window 1 Jun 00 thru 1 Sep 00) LEAD MOBILITY WING 319 ARW Grand Forks AFB</p> <p>Assigned Squadrons: C-130 40 AS Dyess AFB / ANG / AFRC KC-135 349 / 384 ARS McConnell AFB / ANG / AFRC KC-10 305 AMW McGuire / 60 AMW Travis AFB C-21 457 AS Andrews / 458 AS Scott AFB</p> <p>On-Call Squadrons: C-130 39 AS Dyess AFB KC-135 22 ARS Mountain Home AFB</p>	<p>AEROSPACE EXPEDITIONARY FORCE 8</p> <p>(Vulnerability Window 1 Jun 00 thru 1 Sep 00) LEAD MOBILITY WING 319 ARW Grand Forks AFB</p> <p>Assigned Squadrons: C-130 ANG / AFRC / 40 AS Dyess AFB KC-135 92 / 96 ARS Fairchild AFB / ANG / AFRC</p> <p>On-Call Squadrons: C-130 39 AS Dyess AFB KC-135 22 ARS Mountain Home AFB</p>

Notes

¹ Bugado, Capt Harold, HQ AMC/LGSWA, electronic mail correspondence, 12 January 2000.

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